INTRODUCTION

“Oil services” refers to upstream oil and gas work outsourced by large suppliers. It is a broad term, and describes tasks ranging from well drilling and completion to supply of offshore platforms. In many ways, the “service” portion of the term is a misnomer, since, for example, a well completion leaves the customer with a product (the well, liner, packing material, etc.).

The oil services sector stocks generally rise and fall with the price of oil. This is to be expected because as oil prices rise, large oil companies are motivated to extract oil from ever more challenging environments, thereby contracting more jobs to oil services companies. The health of the sector can be assessed by following the PHLX Oil Services Index (OSX).

At this writing (October 2006), crude oil prices have just rebounded from a seven month low. The general decrease over the last several months has led to lower oil services stock prices over this period. While the price of oil has been volatile recently, increasing global demand requires increased production. Even though many in the industry would not subscribe to the “peak oil” theory, which states that global production will soon fall as demand continues to rise, the large majority understand the need for more advanced technology to retrieve oil from challenging environments, such as the ocean floor, as the more readily available supplies are depleted.
Figure 1 shows the OSX and crude oil price history over the past five years. The last six months notwithstanding, the long term trend is on the rise. In September 2006, the Federal Reserve Bank of Dallas reported that, “Demand for oil services and machinery remained strong, with continued large backlogs and limited service capacity. Service firms reported pricing leverage, and said they are building most of their increased revenue supporting strong international activity.”

Nonetheless, short term oil price volatility will place pricing pressure on oil services companies. This requires advancing technology as efficiently as possible. Engineering simulation is a key to this growing efficiency.

ENGINEERING SIMULATION AND FLOW MODELING

With the rise in computer speed and storage capabilities over the last 20 years, engineering simulation has migrated from mainframe computers in R&D departments to the desktops of every designer. The advancement of simulation technology has accelerated in recent years such that analyses that were not considered even one year ago, have become tractable and for some companies, routine. This pace of advancement provides tremendous opportunities for those who embrace it through costs savings, an opportunity to create substantial competitive advantages, and other benefits as described below. Applications for simulation technology in oil and gas include structural design of downhole tools, reservoir simulation, flow assurance in pipeline networks, valve performance, pump design, screen erosion, well packing, etc. This white paper focuses on the simulation tool known as computational fluid dynamics (CFD) and its impact on the emergence of new technologies for the oil services sector. Oil services companies benefit from CFD analysis through cost savings and reliability improvements, as outlined below.

THE BENEFITS OF USING FLOW MODELING SOFTWARE

Cutting Costs

Most oil and gas production operations involve processes that are difficult to monitor or observe. Flow simulation helps engineers to understand the details of a process by providing information about the full three-dimensional flow field. This insight helps engineers understand how a given design will perform and offers clues about improving performance. Engineers can then implement design changes and evaluate the changes in a virtual environment. This virtual environment can often simulate true operating conditions better than experiments, allowing engineers to consider many more design options and obtain additional insight into performance. Drill bit design and mud removal are two examples of how large cost savings resulted from simulation studies.

Drill Bit Design

In the design of drill bits, designers often look to maximize the operating speeds of a bit. Increased drilling speed results in shorter drilling time, a significant cost in the development of a field. Drilling speed is highly dependent on the ability of the drilling fluid to remove cuttings. In a typical configuration drilling fluid flows from nozzles located on the surface of the drill bit such that cuttings are easily ejected upwards, away from the bit. Variations in nozzle location and cutter design can have a major impact on drilling speed and bit longevity. Pluere used fluid flow simulation technology to optimize the roller cone drill bits shown in Figure 2. In this particular case, the design parameter investigated was the location and angle of the mud nozzles. The level of cleaning is indicated by fluid shear stress on the bit and hole bottom surfaces. The type “E” bit maximizes the cleaning of both the roller cones and the bottom hole. By manipulating nozzle location, the designer was able to create a design that showed a 19% improvement in drilling speed over type “D” and a 29% improvement over type “A.”
Mud Removal

After a well is drilled, cement is injected in an annular region between the side wall and a casing for stabilization purposes. The mud that occupies the space between the casing and side wall is displaced by the cement. It is critical that when cement is injected, as much mud as possible be removed from the gap between the riser and side walls of the well bore. If this is not done properly significant production problems may ensue. Schlumberger Dowell used simulation tools to analyze the displacement of mud in this region and the effect of fluid rheological properties such as yield stress and viscosity on mud removal. Figure 3 shows the results of two such simulations. Red represents the cementing material that is injected into the well. Blue represents the mud. These analyses showed that when the yield stress and viscosity were higher in the cement, as shown in a), less mud is left on the annulus walls.
Ensuring Equipment Reliability

Reliability of equipment has become more critical as wells are being drilled in increasingly difficult environments such as offshore and deep repositories. Of course, reliability is related to cost, and part failure below the ocean floor can lead to longer delays in production than in traditional drilling environments, causing enormous financial losses. Flow modeling analysis is allowing oil services engineers to test and optimize equipment virtually, thereby reducing risk of failure in the field, and helping engineers “get it right the first time” rather than taking a costly trial and error approach.

Optimizing Oil Tool Design

New wells are often being drilled in areas where temperatures and pressures are significantly higher than in the past. These environments present significant challenges to tool designers. Flow modeling technology has played a major role in helping designers overcome these challenges. One key simulation parameter for oil tools erosion prediction. Predicting the location of trouble spots and the erosion rate at these locations allows engineers to design robust tools for harsh environments without the need for multiple costly tests. Baker Oil Tools2 uses CFD to predict erosion in its tools. Figure 4 shows the level of erosion prediction accuracy that can be achieved when combining laboratory measurements with computation.

Improving Pipeline Flow

Oil and gas pipelines present several challenging engineering problems. Many of these challenges involve multiphase flow and are compounded by the tremendous distances covered by pipelines as well as changing operating conditions that occur throughout their life. The recent shut-down of part of Alaska’s North Slope and the ensuing controversy illustrates the importance of pipeline capacity and availability in today’s environment of high oil and gas demand.

One major goal in the design of pipelines is to minimize the pipe diameter and wall thickness. Savings realized from small changes to pipe diameter can result in hundreds of millions of dollars for a pipeline installation. However, given the corrosive nature of the transport materials and the fact that sand and small droplets often impact the inside of the pipeline, the design challenge is significant. Like the oil tool engineer, the pipeline engineer has a key concern regarding erosion and corrosion prevention. In-situ troubleshooting while eliminating costly downtime is only possible when a reasonable engineering understanding of the pipeline flow is acquired.
Computational flow modeling provides the insight required to meet these challenges. By using flow simulation, engineers can:

- Predict unsteady pressure drop for junctions and slopes under different conditions
- Estimate erosion rates and locations
- Calculate the unsteadiness of flow caused by slug motion
- Predict valve performance for multiphase flow
- Visualize the flow in order to guide the development of improvements
- Quantitatively determine local pressures and flow velocities within the pipeline

The linked animation (see Figure 5) shows slugging of oil and air in a short pipeline slope and junction computed by flow simulation. This sort of prototyping allows for virtual engineering of pipelines without physical testing, and helps to avoid costly pipeline downtime through increasing flow stability.

Stabilizing Offshore Structures

With increasing storm strengths, particularly in the Gulf of Mexico, seakeeping is becoming an important aspect of risk management. Reliability of offshore rigs not only impacts production, but also reduces liability risks. In addition to wind and wave loading, there are other flow-related phenomena that are relevant to offshore structure reliability, including gas dispersion, helipad safety, fire safety, and current-induced spar and riser motion.

As one example, Figure 6 shows computed wind vectors near an FPSO (Floating Production, Storage and Offloading vessel) helipad. It is critical for safe take-off and landing that vertical velocities are minimized and that temperatures (possibly influenced by ship engine exhaust) are below threshold levels. Flow modeling allowed Kerr-McGee North Sea (U.K.) Ltd. to investigate worst case scenarios quickly, ensuring safety rule compliance.

Vortex Induced Motion (VIM) of risers, spars, and other submerged structures has become an important safety and reliability concern for offshore production. High amplitude oscillations can cause riser collision or fatigue in risers and spar cables. Recent efforts have validated virtual flow modeling for this application, opening the door for investigating strake and fairing effectiveness using simulation. The linked animation in Figure 7 shows vortex structures colored by velocity magnitude downstream of a cylinder experiencing VIM.
CONCLUSIONS

The health of the oil services industry sector typically scales with crude prices. While there has been some concern over oil price volatility, demand for oil services remains strong. All indications point to increasing demand for production in more and more challenging environments and conditions. The instability of oil prices means that oil services companies need to protect their margins by working efficiently. Engineering simulation and flow modeling, in particular, are tools that are helping them accomplish this. Computational fluid dynamics is being used throughout the production process to lower internal engineering services costs, increase hardware reliability, and reduce risk.

1 http://dallasfed.org/research/beige/bb060906.html